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NEW CONCEPT ABOUT STIFFNESS OF GUITAR SOUNDBOARD BASED ON GOLDEN SECTION NUMBERS

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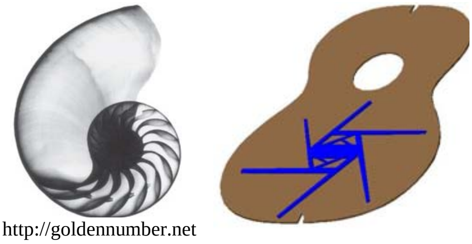
ABSTRACT
The paper presents a new concept about stiffness of guitar soundboard based on golden section number. The traditional strutting systems were replaced with another pattern which was designed according with golden ratio. Experimental researches about dynamical behaviour of new guitar body were performed. The results in terms of Chladni figures, frequency response, power spectral density and sound pressure level were compared with the previous studies.
Keywords: golden section number, guitar, Chladni figures, frequency response, sound pressure level

1. REGARDING GOLDEN RATIO IN CLASSICAL GUITAR CONSTRUCTION
From ancient time, the mathematicians have studied the golden ratio known in literature as golden section or *phi* (in Greek language) or *sectio aurea* (in Latin) [2]. The golden ratio has many applications in mathematics (especially geometry), in architecture, picture, music, nature [1]. The value of φ is 1,618033. Two quantities *a* and *b* are said to be in the golden ratio φ if:

$$\frac{a+b}{a} = \frac{a}{b} = \varphi = 1.618 \qquad (1)$$

In classical guitar construction, the golden section is present directly or indirectly in ratios between different dimensions of guitar parts.
The guitar's acoustical quality is determined by numerous factors, such as: the plates' geometry and structure, the quality of the materials and their physical, elastic, mechanical and acoustical characteristics, the surfaces' quality and the finishing, the strings' quality and the musician's skillfulness etc. One of the most important parts of guitar is the body which presents one of the strutting systems such as: top plate with reinforced strips disposed transversal to the axis, top plate with 3 radial braces, top plate with 5 radial braces, top plate with 3 radial braces and 2 in V pattern, top plate with 5 radial braces and 2 in V pattern and top plate with 7 radial braces and 2 in V pattern.
Starting from the golden spiral, we designed a new concept to stiffen the top plate of classical guitar which is similarly with nautilus shell as can be seen in Figure 2 [4]. Some differences between our shape and shell spiral can be noticed in Figure 2. The shape of stiffness pattern was performed by means of numerical control machine tool. It was used several types of material based on wood such as:

Spruce - solid wood, plywood from Spruce, Mahogany and Lime. Then the spirals were glued on the inner of top plate.



http://goldennumber.net

Figure 2. The stiffness pattern based on golden spiral

2. EXPERIMENTAL SETUP

Using the experimental stand displayed in Figure 3, the signals of classical guitar bodies were measured with recording and processing soft of Pulse system. Each guitar body was freely supported on a foam device and excited with a B&K mini-shaker located on a bridge area of the top plate. The input signal was measured with a force transducer and the forced vibrations of each structure (the output signal) were captured with three B&K 4517-002 type accelerometers (measuring on z direction). The recording and processing of signals in time and in frequency domain it was performed by means of B&K Pulse 12 system connected to the personal computer.

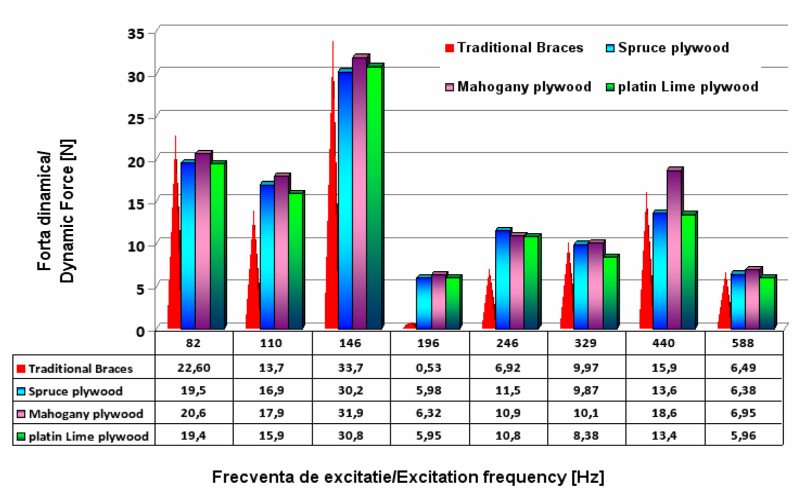
Figure 4. Experimental setup

It is known that one of the most important characteristics of the stringed instruments is the possibility of resonating at the excitation frequency of the strings. For this reason, the frequencies of harmonic force: 82, 110, 146.83, 196, 246.9, 329.2 Hz (specific with the strings of guitar frequencies) and 440 Hz (la – musical note), 588 Hz (third frequency of 196 Hz) were generated through frequency generator [3].

3. RESULTS AND DISCUSSION

In Figure 5 it can be noticed that the dynamic forces of all types of new models have similarly values, especially in case of new stiffening models. Between traditional braces pattern and the new one some differences appear. According to variation of dynamic forces the studied cases have a stable behaviour regardless of excitation frequencies.

From Figures 5, 6 it can be noticed that all guitar bodies with the new stiffening pattern have in common two values of resonance frequency: 760 Hz and 1016 Hz. Some interesting aspects is related to the number of resonance frequencies which is bigger than the traditional braces system. All species selected for golden spiral increase the capacity of acoustic box to vibrate and amplify a numerous harmonics.



	82	110	146	196	246	329	440	588
Traditional Braces	22,60	13,7	33,7	0,53	6,92	9,97	15,9	6,49
Spruce plywood	19,5	16,9	30,2	5,98	11,5	9,87	13,6	6,38
Mahogany plywood	20,6	17,9	31,9	6,32	10,9	10,1	18,6	6,95
platin Lime plywood	19,4	15,9	30,8	5,95	10,8	8,38	13,4	5,96

Figure 5. Variation of dynamic force with excitation frequency and type of structure

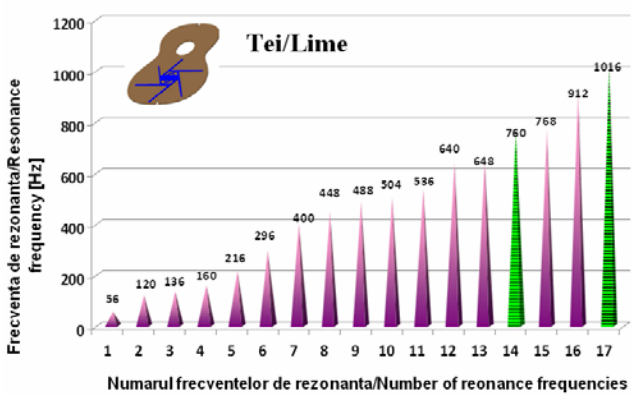


Figure 6. The range of resonance frequency obtained in case of lime plywood

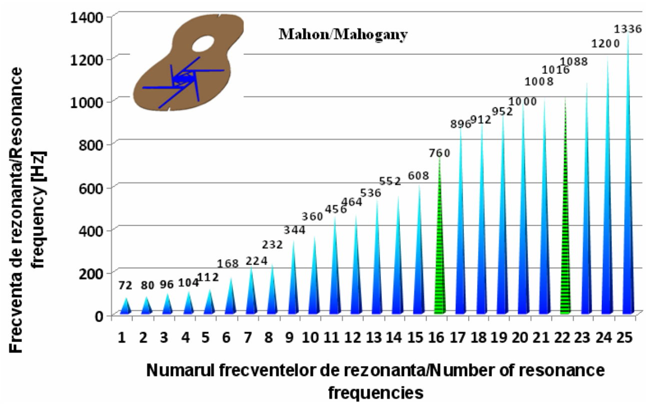


Figure 7. The range of resonance frequency obtained in case of mahogany plywood

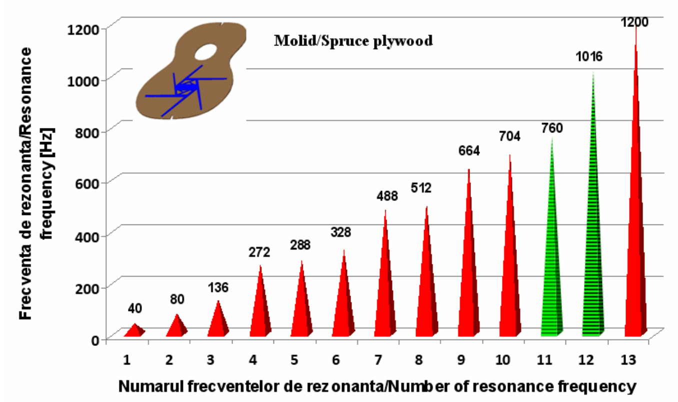


Figure 8. The range of resonance frequency obtained in case of spruce plywood

4. CONCLUSIONS

The results performed by now lead to the conclusion that the new design of strutting system of guitar body has structural properties proper to increase the acoustical performances of guitar. This has a practical importance because it could be noticed that in terms of acoustics and musical, the low and medium frequencies (between 80-380 Hz) are responsible for the sound's radiation through the structure of the guitar. In the same time, the new model has advantages that replace the bridge braces and assure the resistance of the thin top plate. Both requirements are fulfilled by the new model glued on the top plates. Stiffening system of top plates of the guitars constitutes another decisive factor in the quality of the dynamical response of the entire structure, the guitar. The paper presented the preliminary studies which will continue with other specific tests (mechanical, acoustical, a.o.) and certain investigation about the costs.

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